Fishery Data Series No. 96-5

Stock Assessment of Arctic Grayling in the Chatanika River During 1995

by

James T. Fish

March 1996

Alaska Department of Fish and Game **Division of Sport Fish**

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd

Spell out acre and ton.

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s

Spell out year, month, and week.

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$log_{2,}$ etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

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STOCK ASSESSMENT OF ARCTIC GRAYLING IN THE CHATANIKA RIVER DURING 1995

by

James T. Fish
Division of Sport Fish, Fairbanks

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599

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James T. Fish
Alaska Department of Fish and Game, Division of Sport Fish, Region III,
1300 College Road, Fairbanks, AK 99701-1599,USA

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ABSTRACT

Abundance and age and length compositions of Arctic grayling *Thymallus arcticus* were estimated for a portion of the Chatanika River, sampled during June of 1995, using a modified Petersen estimator. The Chatanika River study area extended from 3.2 km above the Elliott Highway bridge downstream to 8.2 km below Any Creek, totaling 37.8 km. Estimated abundance of Arctic grayling ≥ 150 mm fork length for the Chatanika River study area was 8,930 fish (SE = 779). Estimated density of Arctic grayling ≥ 150 mm fork length within the Chatanika River study area was 236 fish per kilometer (SE = 21). The density of age-3 fish was 19 fish per kilometer (SE = 3) and the proportion of age-3 fish was 0.08 (SE = 0.01). The density of Arctic grayling ≥ 270 mm fork length was 87 fish per kilometer (SE = 9) and the proportion of Arctic grayling ≥ 270 mm fork length was 0.37 (SE = 0.02).

Key Words: Arctic grayling, *Thymallus arcticus*, population abundance, age composition, length composition, electrofishing, Chatanika River, Tanana River drainage.

INTRODUCTION

The Chatanika River is a runoff stream that flows southwest out of the White Mountains, draining through Minto Flats into the Tolovana River (Figure 1). The Chatanika River is formed by the confluence of Faith and McManus creeks. This river parallels the Steese Highway for approximately 70 km, continues in a westerly direction past the Elliott Highway, and continues on to the Tolovana River. The Chatanika River sampling area is characterized by moderate gradient, meandering stretches, narrow to wide channels, and exposed gravel bars. There is a history of placer mining within the Chatanika River drainage. As of 1995, there were placer mining operations on portions of Faith, Sourdough, Pool, Smith, and Flat creeks of the upper Chatanika River (A. H. Townsend, Alaska Department of Fish and Game, Fairbanks, personal communication).

The Chatanika River fisheries are road accessible along the Steese Highway, from the Elliott Highway bridge, and at the end of Murphy Dome Road extension. A boat ramp, parking lot, picnic and camping area are available at the Elliott Highway bridge, a camping and picnic area at 101-km Steese Highway, and a campground at 98-km Steese Highway. However, access to the study area is limited to river boat, launched from the Elliott Highway bridge boat ramp or a gravel bar at the end of Murphy Dome Road extension.

More than 50% of all fish caught by sport fishermen (released or kept) in the Chatanika River in 1993 were Arctic grayling (Mills 1994). In addition to Arctic grayling, fish caught in the Chatanika River in 1993 included (from greatest to least number caught): northern pike *Esox lucius*, chinook salmon *Oncorhynchus tshawytscha*, whitefish *Coregonus* spp. and *Prosopium cylindraceum*, coho salmon *O. kisutch*, and sheefish *Stenodus leucichthys* (Mills 1994).

Prior to 1977, information collected from anglers fishing for Arctic grayling in the Chatanika River was sparse. Creel survey data for harvest rates were obtained during the summers of 1953 through 1958 and 1974. Harvest rates ranged from 0.13 Arctic grayling per hour to 0.78 Arctic grayling per hour from 1953 through 1958 (Warner 1959); and 1.02 Arctic grayling per hour in 1974 (Kramer 1975).

Each year since 1977, Mills (1979-1994) estimated annual harvest and effort on the Chatanika River through a postal survey (Table 1). Average annual harvest of Arctic grayling on the Chatanika River was 5,578 fish, ranging from a high in 1983 of 9,766 and a low in 1992 of 1,751.

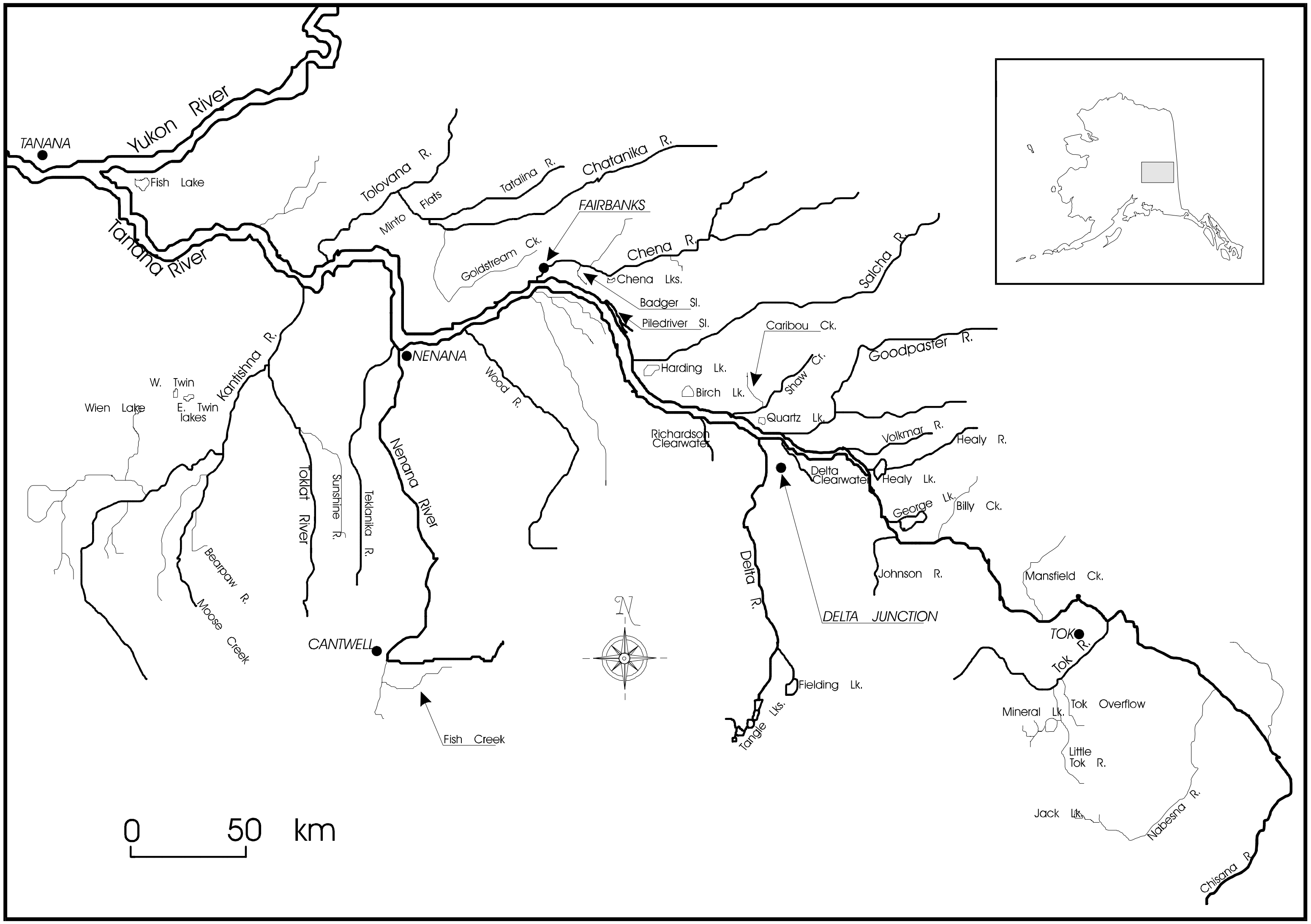

Figure 1.-The Tanana River drainage.

Table 1.-Arctic grayling effort, harvest, and catch in the Chatanika River, 1977-1993 (Mills 1979-1994).

Year	Effort[a]	Harvest[b]	Catch[c]
1977	9,925	8,167	ND[d]
1978	10,835	9,284	ND
1979	4,853	6,121	ND
1980	5,576	5,143	ND
1981	4,691	3,808	ND
1982	9,417	6,445	ND
1983	10,757	9,766	ND
1984	8,605	4,180	ND
1985	10,231	7,404	ND
1986	7,783	2,692	ND
1987	11,065	5,619	ND
1988	11,642	8,640	ND
1989	12,210	6,934	ND
1990	11,801	4,237	17,960
1991	8,085	2,642	12,830
1992[e]	6,775	1,751	11,570
1993[e]	7,671	2,001	14,283
Averages	8,937	5,578	14,161

[a] Effort is the number of angler-days expended for all species of fish.

[b] Harvest is the estimated number of Arctic grayling caught and kept.

[c] Catch is the estimated number of Arctic grayling caught (kept or released).

[d] ND = data not available.

[e] Special regulations were in effect on a portion of the Chatanika River. These special regulations were; catch and release Arctic grayling fishing from 1 April to the first Saturday in June; 12 inch (305 mm) minimum length limit; and, artificial lures or flies only.

Average effort in the Chatanika River for all species of sport fish was 8,937 angler-days, ranging from a high in 1989 of 12,210 angler-days to a low in 1981 of 4,691 angler-days. In addition, each year since 1990, Mills (1991-1994) estimated annual fish caught (fish harvested plus fish caught and released) in the Chatanika River (Table 1). The average annual catch of Arctic grayling in the Chatanika River from 1990 through 1993 was 14,161 fish. In addition to the 1987 harvest data provided by Mills (1988), Baker (1988) estimated that the catch rate near the Elliott Highway bridge was 0.21 (SE = 0.14) Arctic grayling per angler-hour fished from May through June 1987.

The low estimated harvest rates in the early 1950's prompted fishery managers to restrict the harvest of Arctic grayling from the Chatanika River to fish 305 mm (12 in) or greater in total length (Wojcik 1954, 1955) between 1955 and 1958. In 1992, restrictive regulations were implemented to protect the Arctic grayling population in the Chatanika River from decline. These regulations were designed to:

1) eliminate the harvest of Arctic grayling from 1 April to the first Saturday in June;
2) restrict methods of catching Arctic grayling during the spawning period to unbaited, single-hook artificial lures; and,
3) restrict the harvest of Arctic grayling to fish > 305 mm (12 in) total length (TL)[1] in the portion of the Chatanika River upstream from a point 1.6 km above the Elliott Highway bridge (no size restriction within the study area).

During Board of Fisheries actions taken in 1994, the length restriction for Arctic grayling was expanded to the entire Chatanika River and its tributaries.

A goal of this study is to provide stock assessment data for Arctic grayling in the Chatanika River to assist area fishery managers in stock management decisions. Precise knowledge of fishery characteristics and population dynamics of Arctic grayling in this stream is important to fishery managers.

The research objectives for 1995 were to:

1) estimate abundance of Arctic grayling (≥ 150 mm FL) in a 28.8 km section of the Chatanika River, such that this estimate is within 25% of the true abundance 95% of the time;
2) estimate age composition of Arctic grayling (≥ 150 mm FL) within the study area of the Chatanika River, such that all proportions are within five percentage points of the true proportions 95% of the time; and,
3) estimate length composition of Arctic grayling (≥ 150 mm FL) within the study area of the Chatanika River, such that all proportions are within five percentage points of the true proportions 95% of the time.

In addition, historical stock-assessment data summaries are presented for the Chatanika River (Appendix A). Although not always directly comparable, these summaries provide an historical context that managers may use to evaluate the results of the present investigation.

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[1] 305 mm TL is approximately equal to 270 mm FL.

METHODS

Specific methodologies have been developed to estimate abundance of Arctic grayling in rivers of interior Alaska. Sampling schemes have evolved from multiple-sample mark-recapture experiments in short index areas (Van Hulle 1968) to single-sample Petersen experiments in relatively longer study areas (Clark and Ridder 1987). This change to longer study areas was made possible, in part, because jet propelled riverboats enabled investigators to sample longer contiguous sections of rivers that were previously not sampled because of shallow runs. In addition, the use of boat-mounted electrofishing equipment has provided a means to capture a greater number of fish and cover longer stretches of river in less time and with less effort. However, as with other sampling methods, electrofishing may be size selective (Reynolds 1983). To correct for length bias from sampling gear and sampling technique, the methodology outlined in Appendix B was followed.

Abundance and stock composition of Arctic grayling were estimated within a 37.8[2] km portion of the Chatanika River in 1995 by using mark-recapture experimental techniques. A marking event occurred June 19-21 and a recapture event occurred June 28-30, with a hiatus of 8 days between events. The Chatanika River study area extended from 3.2 km above the Elliott Highway bridge downstream to 8.2 km below Any Creek (Figure 2). The longer study area, in general, minimizes the proportion of fish that immigrate or emigrate during the experiment. The study area was divided into three approximately equal sections to evaluate movement. To standardize effort, each section was divided into several electrofishing runs (the distance covered during 20 min of active electrofishing, approximately 1.9 km).

The electrofishing boat had a crew of three; two captured fish with dip nets and one piloted the boat. The boat was equipped with a pulsed DC variable voltage pulsator (VVP; Coffelt Model VVP-15) powered by a 3,800 W single-phase gasoline generator. Anodes consisted of four 15 mm diameter steel cables (1.5 m long) arranged perpendicular to the long axis of the boat and 2.1 m forward of the bow. The unpainted bottom of the aluminum boat was used as the cathode. Settings on the VVP were standardized at 60 Hz and 50% duty cycle (duty cycle is the duration the electrical pulse is on during one cycle, expressed as a percent of the cycle). At a given voltage, amperage varied according to the conductivity, substrate, and water depth of the river. The boat operator, however, made every effort to keep the output constant to minimize fish injury and mortality. Voltage was adjusted at the VVP to keep the output at $<$ 5 amperes as conditions changed.

Sampling was spread evenly down the river with equal effort throughout the study area. Each sampling event started at the upstream boundary of the study area and continued downstream. During the marking and recapture events, one electrofishing boat fished in a downstream direction, alternating between each bank, for a standard 20 min run. During a run, as many Arctic grayling as possible were captured with dip nets and placed in a holding tub that was aerated with running water. At the end of each run fishing ceased; fish were sampled and released before continuing. Before release, the fork length of each captured fish was measured to the nearest mm, scales were taken for age determination (during the recapture event only), a Floy FD-68 internal

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[2] The 28.8 km proposed study area was lengthened to 37.8 km because of extra time and the fact that a larger study area increases the accuracy of the abundance estimate.

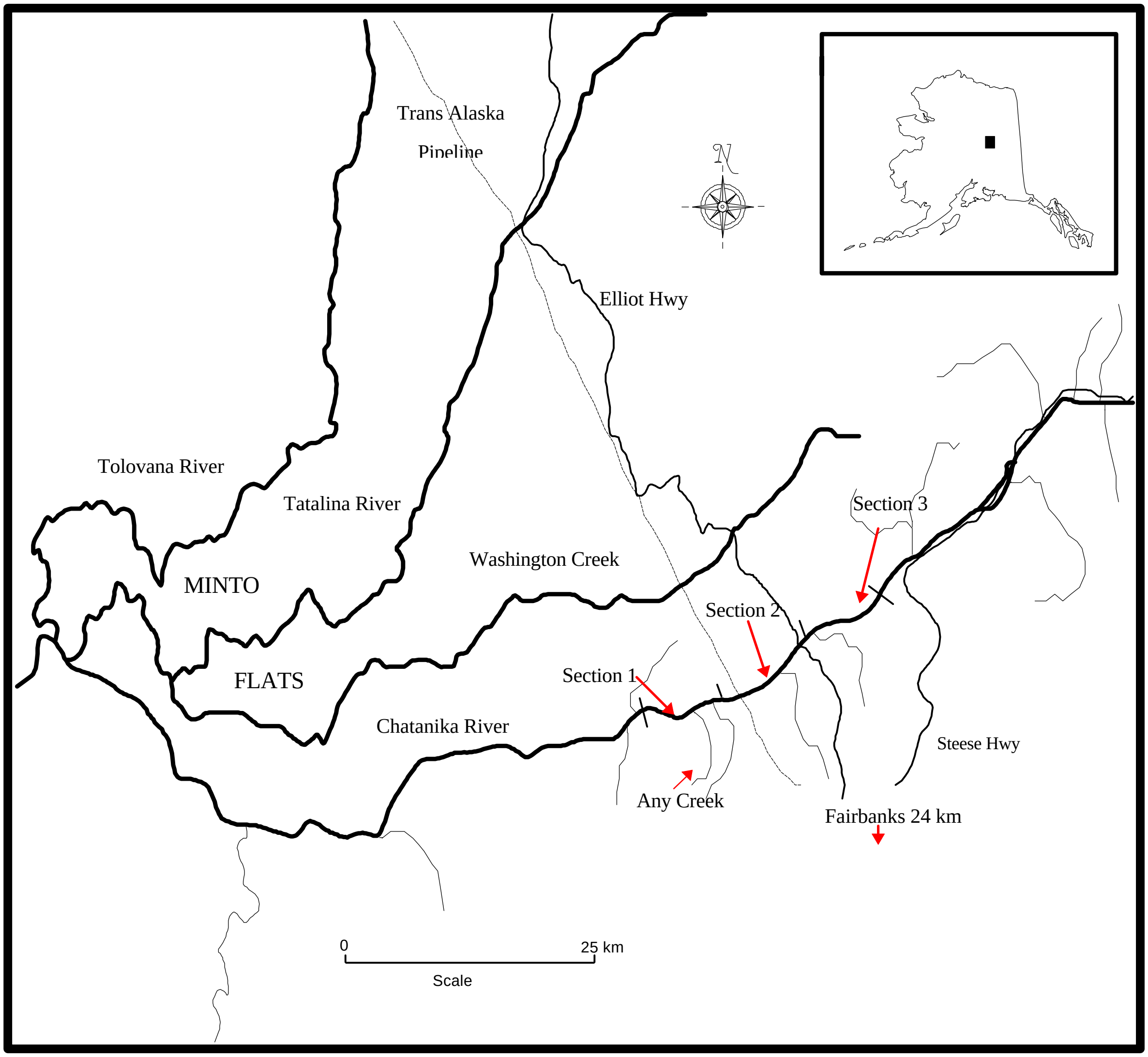

Figure 2.-The Chatanika River drainage with the 1995 study area delineated.

anchor tag was attached (during the marking event only), and a fin was clipped as a double mark. Run boundaries were either marked with flagging or a unique landmark was noted in field notes or on a topographic map.

Two scales were taken from each captured fish during the recapture events. All scales came from an area on the fish centered approximately six scale rows above the lateral line and just posterior to the insertion of the dorsal fin (W. Ridder, Alaska Department of Fish and Game, Delta Junction, unpublished information on refinement of methods described by Brown 1943). Scales were placed on gum cards in the field and retained for future processing and reading. Impressions of the scales were made on triacetate film using a scale press (30 s at 137,895 kPa, at a temperature of 97°C). Ages were determined by counting annuli from impressions of scales magnified to 48X with the aid of a microfiche reader. Criteria for determining the presence of an annulus are: 1) complete circuli cutting over incomplete circuli; 2) clear areas or irregularities in circuli along the anterior and posterior fields; and, 3) regions of closely spaced circuli followed by a region of widely spaced circuli (Kruse 1959). Determination of age was performed only once for each readable set of scales and all scales were read by one reader.

All data pertaining to age, length, sampling induced mortality, tag identification numbers and colors, capture location (by run and river section), finclips, recapture status, and tag loss were recorded on mark-sense forms and electronically stored for analysis and archival (see listing of data files in Appendix C1).

ESTIMATION OF ABUNDANCE

Abundance of Arctic grayling ≥ 150 mm FL was estimated for the Chatanika River study area with a modified Petersen single-sample estimator (Seber 1982), which in this experiment assumes:

1) the population is closed (no change in the number or composition of Arctic grayling in the population during the experiment);
2) all Arctic grayling have the same probability of capture during the marking event <u>or</u> the same probability of capture during the recapture event <u>or</u> marked and unmarked Arctic grayling mix completely between the marking and recapture events;
3) marking of Arctic grayling does not affect their probability of capture in the recapture event;
4) Arctic grayling do not lose their mark between events; and,
5) all marked Arctic grayling are reported when recovered in the recapture event.

Assumption 1 was not tested directly, but examination of fish movement from one section to another was used to infer significant movement of fish out of, or into the study area. Mortality, recruitment and growth, which may also contribute to the violation of assumption 1, were assumed to be negligible because of the short duration of the experiment (12 days from beginning to end).

Assumptions 2 and 3 were evaluated by a series of tests that were designed to detect unequal catchability (rates of capture or recapture, or capture probability) and gear selectivity, which violate these two assumptions. These tests included a chi-square contingency table test that compared capture probability by river section, inspection of movement, and two Kolmogorov-Smirnov two-sample tests that compared capture probability by length. The results of these tests, in combination, determined the methods used to compensate for bias in the abundance estimation. Probabilities of a Type I error (α) of 0.05 or lower were considered significant.

Specifically, the chi-square tests compared capture probability among sections during the recapture event (the frequency of fish with marks to the frequency of fish without marks). Inspection of movement was an empirical comparison of fish with marks that moved from one section of the river to another section between events to fish with marks that stayed in the same section. Movement was determined to be significant if more than 10% of fish marked in one section were recaptured in another section. Using the results of these tests, Appendix B1 outlines the methodology used to determine stratification by area and choice among possible estimators, which are summarized in Appendix B3.

After evaluating equal capture probability by river section, equal capture probability by length was addressed for the complete study area. Kolmogorov-Smirnov two-sample tests were used to compare: 1) the length frequency distributions of recaptured Arctic grayling with all Arctic grayling captured during the recapture event; and 2) the length frequency distributions of Arctic grayling captured during the marking event with those captured in the recapture event. Using the results of these tests, Appendix B2 outlines the methodology used to determine stratification by length and choice among possible estimators, which are summarized in Appendix B3.

Double marking allowed investigators to test assumption 4. Tag loss was noted when a fish was recovered with a specific fin clip but without a Floy tag. In addition, Floy tag placement was standardized, which enabled the fish handler to verify tag loss by locating recent tag wounds.

Violations of assumption 5 were minimized by a thorough examination of the fins of each fish for clips and the recording of fin clips and Floy tag numbers whether the fish was believed to be a recaptured fish or not.

ESTIMATION OF LENGTH AND AGE COMPOSITIONS

Length and age compositions of Arctic grayling ≥ 150 mm were estimated for the Chatanika River study area. The integrity of composition estimates relies on the same assumptions as for abundance estimates. Unequal movement by length or age and gear selectivity by length or age violate these assumptions. Methodology to compensate for bias from violation of these assumptions is outlined in Appendices B1, B2, and B4 for the estimate of length composition. Age composition was estimated from samples from the recapture event. There may be bias associated with the estimates of these age compositions for three reasons: 1) equal catchability by age was not directly tested (it may not be necessary to test because age and length are correlated); 2) all fish in a sample were not aged (fish that were aged were not randomly selected; scales from larger fish were likely less readable); and, 3) fish < 150 mm FL were not included regardless of age (for example, the estimated proportion of age-2 fish does not include all age-2 fish but only age-2 fish that are ≥ 150 mm FL).

RESULTS

Investigators handled 1,408 unique Arctic grayling ≥ 150 mm FL during the Chatanika River mark-recapture experiment which had a duration of 12 days from beginning to end, and a hiatus of 8 days between marking and recapture events During the marking event (June 19-21), 862 Arctic grayling were tagged and released alive. During the recapture event (June 28-30), 597

Arctic grayling were examined for marks. Of these 597 fish, 546 were unique and 51 were recaptured from the marking event. Of the 51 recaptured fish, none lost their tags between marking or recapture. During the marking event 10 Arctic grayling were killed or severely injured (1.2% of fish handled during the marking event). These fish were not included in the experiment. During the recapture event there were four Arctic grayling killed ($<$ 1% of fish handled during the recapture event). These fish were included in the experiment. Investigators identified 102 Arctic grayling (7.2% of unique fish handled) from prior mark-recapture experiments.

Abundance

Estimated abundance of Arctic grayling within the Chatanika River sampling area was germane to fish ≥ 150 mm FL during the last half of June 1995. The recapture rates, or capture probability during the recapture event, of Acrtic grayling within each of three approximately equal-length river sections was calculated as the number of fish recaptured divided by the number of fish caught and examined for marks in the recapture event; R/C. The recapture rate in the upper river section (Section III) was 0.07; 0.09 in the middle river section (Section II); and 0.12 in the lower river section (Section I; see Figure 3). The recapture rate throughout the study area averaged 0.09 (calculated by adding the rates for each section and dividing by the number of sections). The recapture rates of Arctic grayling within the study area were not significantly different among the three approximately equal-length river sections ($\chi^2 = 2.32$, 2 df, $P = 0.25$; Figure 3), thus stratification by river section was not necessary.

Comparison of sections where Arctic grayling were marked with sections where the fish were recaptured indicated movement between sections (Table 2). Of recaptured Arctic grayling with known capture histories by location, 12 of 51 fish (24%) moved upstream from one section to another between marking and recapture events. This movement was considered to be biologically meaningful because of its magnitude, direction, timing, and possible association with environmental conditions. In addition to upstream movement, three fish (6%) of 51 recaptures moved downstream. However, this was not considered to be unusual and is thought to be consistent with sampling-induced patterns of riverine fish movement during mark-recapture experiments utilizing electrofishing techniques.

A lack of significant differences in capture probability between river sections indicated that the mark-recapture experimental assumption of equal probability of capture <u>or</u> equal probability of recapture <u>or</u> complete mixing of marked and unmarked fish between marking and recapture events was not violated. However, there was clearly directional movement of fish between river sections, indicating that the experimental assumption of closure may have been violated. Therefore, case II of the experimental methodology outlined in Appendix B1 (null hypothesis of equal catchability cannot be rejected, but movement between sections was observed) was followed. An unstratified estimate of abundance using the Bailey (1951, 1952) estimator and an unstratified estimate of abundance using the "movement" (Evenson 1988) estimator were calculated.

Using the Bailey estimate, the estimated abundance of Arctic grayling in the Chatanika River study area was 9,913 fish (SE = 1,301, CV = 13.1%), while the movement estimate of abundance was 8,930 fish (SE = 779, CV = 8.7%). Comparison of both estimates for similarity revealed that there was a difference of approximately 10% between estimates. One could conclude that these estimates were likely similar. However, considering that 24% of recaptured fish moved upstream

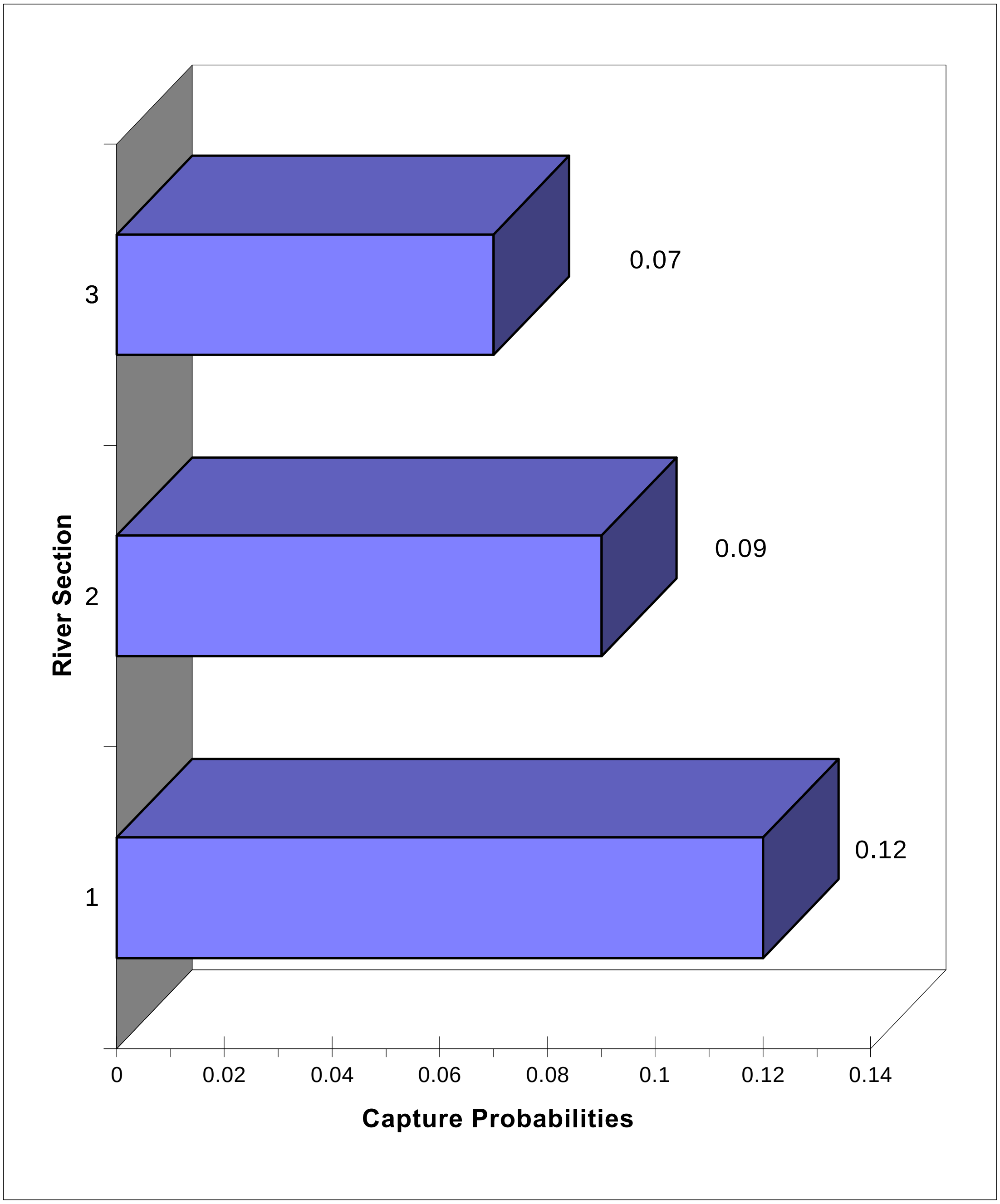

Figure 3.-Estimated capture probabilities (number of fish marked in the marking event and recaptured in the recapture event divided by the total number of fish captured in the recapture event) in three sections of the Chatanika River in June 1995.

Table 2.-Number of Arctic grayling recaptured in a section and run (n = 51) of the Chatanika River summarized by the section and run in which the fish was marked.

Mark	Number Recaptured																				Number Moved
	Section III						Section II								Section I						Between
Run[a]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Sections
1	1	1																			0
2																					0
3				1																	0
4			3	1																	0
5					3	1															0
6						2	1														1
7						1	3														1
8			1						1											1	2
9										1				1							0
10							1														0
11											2					1					1
12		1									1	1									1
13			1				1					1									1
14		1												1							1
15						1		1							1						2
16										1						1		1			1
17							2							1			2				3
18																		1			0
19																			2	1	0
20									1												1
Tot	2	3	5	2	3	5	8	1	2	2	3	2	0	3	1	2	2	2	2	2	51/15

[a] A run was approximately 1.9 km; the distance covered by a 20 min downstream pass of an electrofishing boat. Run 1 started 3.2 km upstream of the Elliott Highway bridge and run 20 ended 8.2 km below Any Creek.

between events to different river sections, and similar movements probably occurred with marked fish that exited, as well as those that entered the study area, the movement of fish between events was considered to be meaningful, in that it violated the assumption that the fish in the study area existed as a closed population. Therefore, as outlined in the experimental methodology of Appendix B1, the estimate calculated from the movement estimator was chosen as the most appropriate estimate of abundance of Arctic grayling in the Chatanika River study area. Estimated density of Arctic grayling ≥ 150 mm FL was 236 fish per kilometer (SE = 21 per kilometer) within the Chatanika River study area.

Length and Age Compositions

There was no significant difference between the length distributions of fish marked and fish recaptured within the study area ($D = 0.14$, $P = 0.24$; Figure 4-A). However, there was a significant difference in the length distributions of fish marked and fish examined for marks ($D = 0.11$, $P = 6.48 \times 10^{-4}$; Figure 4-B). These results indicated that there was no difference in capture probability by length during the recapture event (see Appendix B2). Therefore, stratification by length was not necessary, and lengths and ages obtained from fish caught during the recapture event were used to estimate the length and age compositions of fish within the Chatanika River study area.

Ages determined from scales of Arctic grayling ≥ 150 mm FL captured during the recapture event were used to estimate the age composition of Arctic grayling ≥ 150 mm FL within the Chatanika River sampling area. Ages were estimated from 491 of 597 fish, and age classes ranged from age-2 to age-12 (Table 3). The age classes with the largest proportion of Arctic grayling ≥ 150 mm FL within the Chatanika River study area were age-4 (0.24, SE = 0.02; Table 3) and age-5 (0.31, SE = 0.02). Density of age-3 Arctic grayling was 19 fish per km (SE = 3 per km).

Fork lengths of Arctic grayling captured during the recapture event were used to estimate length composition of Arctic grayling in the Chatanika River. Fork lengths measured from 593 Arctic grayling from the Chatanika River sampling area ranged from 150 to 379 mm FL (mean = 256 mm, SE = 2 mm). The proportion of Arctic grayling ≥ 270 mm FL was 0.37 (SE = 0.02), for a density of 87 fish per km (SE = 9 per km; see also Figure 5).

DISCUSSION

An inspection of known locations of marked fish recaptured revealed movement of fish across river section boundaries. Distances traveled by individual fish ranged from approximately 1.9 to 22.8 km over a period of 7 to 11 days. Of 12 fish that moved upstream, four (33%) moved a distance of approximately 19 km. During past mark-recapture experiments, fish have been observed to move one or more sampling runs downstream (see Roach 1995 where only five of 98 recaptures exhibited sectional movement in August). Fish are in fact released downstream from their initial capture location during electrofishing sampling procedures. Typically, fish are sampled sequentially as they are encountered by the electrofishing boat moving downstream, and are tagged and released downstream at the end of each sampling run. This sampling-induced displacement of fish may simply be the cause of observed fish movement downstream by one or more sampling runs. However, 24% of 51 recaptures displayed upstream movement, and covered a distance of 1 to 12 sampling runs from the place of initial capture, clearly indicating directional

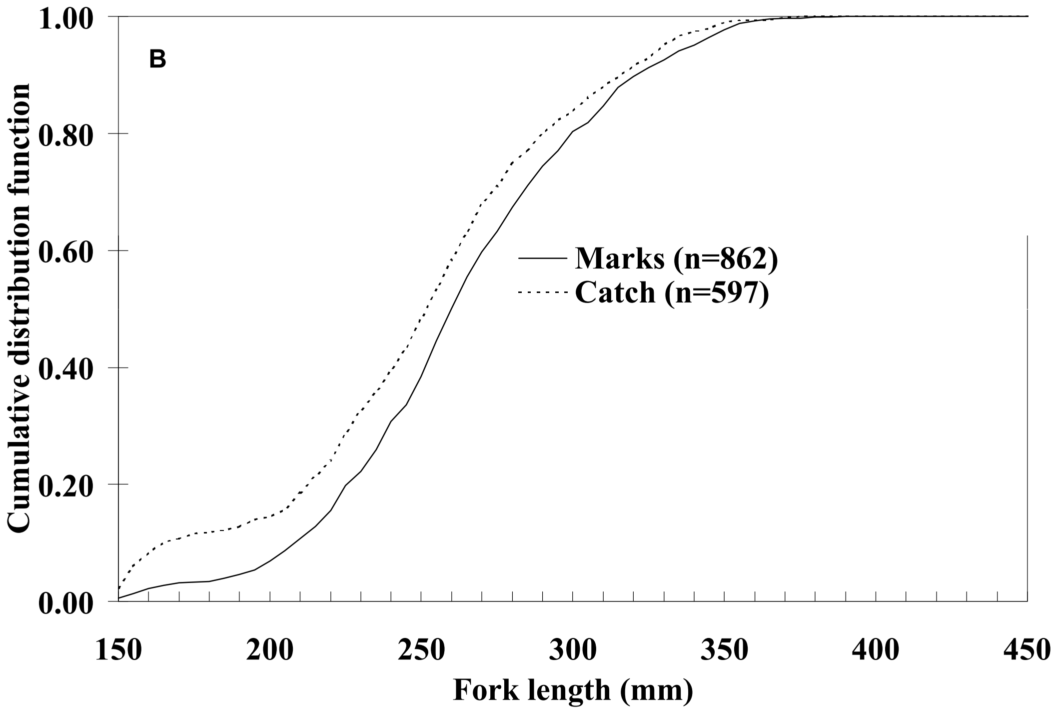

Figure 4.-Cumulative distribution functions of fork lengths of Arctic grayling captured in the Chatanika River study area in June 1995. (A) Arctic grayling marked versus Arctic grayling recaptured; and (B) Arctic grayling marked versus Arctic grayling examined for marks in the recapture event.

Table 3.-Estimated abundance (N), standard error of abundance (SE[N]), sample size (n), proportion (p), and standard error of proportion (SE[p]) of Arctic grayling ≥ 150 mm FL by age within the Chatanika River study area.

Age Classes	N	SE[N]	n	p	SE[p]
2	1,049	152	66	0.12	0.01
3	731	121	46	0.08	0.01
4	2,225	253	140	0.25	0.02
5	2,797	300	176	0.31	0.02
6	683	117	43	0.08	0.01
7	858	134	54	0.10	0.01
8	461	93	29	0.05	0.01
9	95	40	6	0.01	<0.01
10	16	16	1	<0.01	<0.01
11	0	0	0	---	---
12	16	16	1	<0.01	<0.01
Totals	8,930	779	562	1.00	

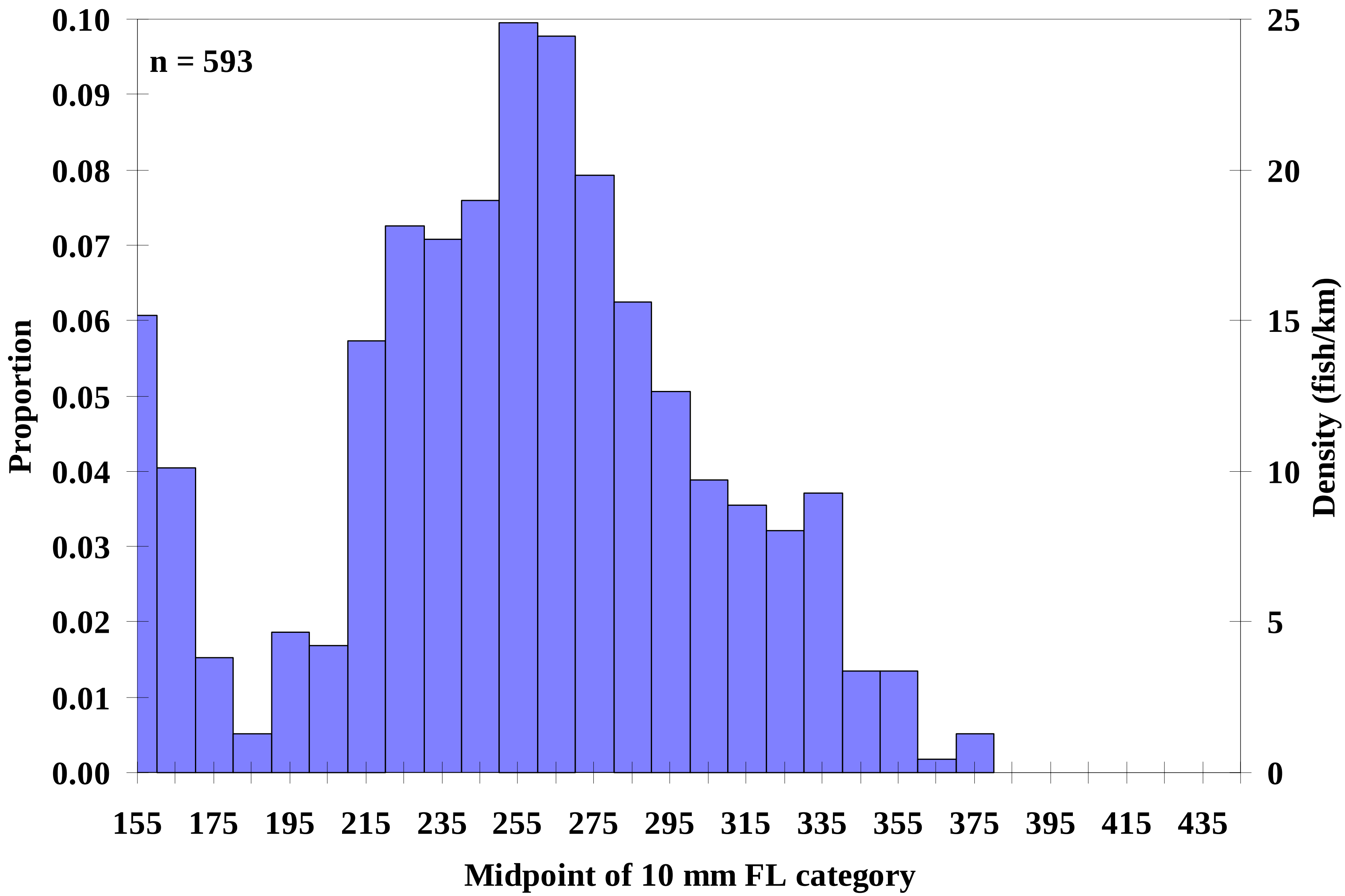

Figure 5.- Estimated proportions and densities of Arctic grayling ≥ 150 mm FL by 10 mm categories in the Chatanika River study area in June 1995.

movement. The mark-recapture experiment was initiated during the month of June to avoid the presence of migrating whitefish, which may be susceptible to injury from electroshocking techniques used to sample Arctic grayling (Holmes et al. 1990). During this time of year Arctic grayling may be moving upstream to summer feeding areas, similar to the movement trends of Arctic grayling inhabiting other river systems, such as the Goodpaster River (Tack 1980). In addition, high water levels caused by heavy rainfall were observed in the Chatanika River prior to the onset of the recapture event. The recapture event was postponed by two days because such high water levels posed difficulties for investigators to sample an acceptable number of fish with electroshocking techniques. What effect high river water levels had on Arctic grayling movement patterns is unclear.

Although movement of Arctic grayling that was detected during the mark-recapture experiment was accounted for by the movement estimator, the amount of movement seen raises concerns as to the validity of a stock assessment performed on the Chatanika River in June. If the stock were in transit to summer feeding areas upstream of the study section, the assessment data may not provide a "snapshot" of the stock on an annual basis. Past assessments (1991 through 1994) were performed in late August, in conjunction with the whitefish assessment; significant (>10% of recaptures) movement of Arctic grayling was not detected during any of these assessments (see Fleming et al. 1992, Ridder et al. 1993, and Roach 1994, 1995). During 1988 through 1994, Arctic grayling in the Salcha River were assessed during late June; the movement estimator was the preferred estimator for five out of seven years (see Clark 1988, Clark and Ridder 1990, Clark et al. 1991, Fleming et al. 1992, Ridder et al. 1993, and Roach 1994, 1995). However, the predominant direction of movements detected in the Salcha River during June were downstream. Movement of post-spawning adults downstream out of the Salcha River into clearwater streams for feeding, sampling induced downstream movements, and downstream flushing of small Arctic grayling by high stream flows were implicated on the Salcha River. It is recommended that stock assessment of the Chatanika River not be continued in June, but resumed in late August if possible.

Alternatively, some insight into the status of Arctic grayling in the Chatanika River can be made from the assessment in 1995. Assessments performed in June do not fully characterize abundance of age-2 Arctic grayling, but it appears that the 1993 year class is much stronger than the 1992 (age-3) year class (Table 3). Roach (1995) found that the 1992 year class was very weak in August of 1994 (~4 fish/km as age-2) as was found in this study (19 fish/km as age-3). Partial recruitment of the strong 1993 year class to the Chatanika River (~28 fish/km as age-2) may explain the slight increase of the point estimate of density observed from August of 1994 to June of 1995 (Figure 6). Density of harvestable size (≥ 270 mm FL) Arctic grayling was similar between 1994 (~85 fish/km) and 1995 (~87 fish/km). Based on these characteristics it appears that the Chatanika River stock has stabilized somewhat since the significant decline in density seen in 1991.

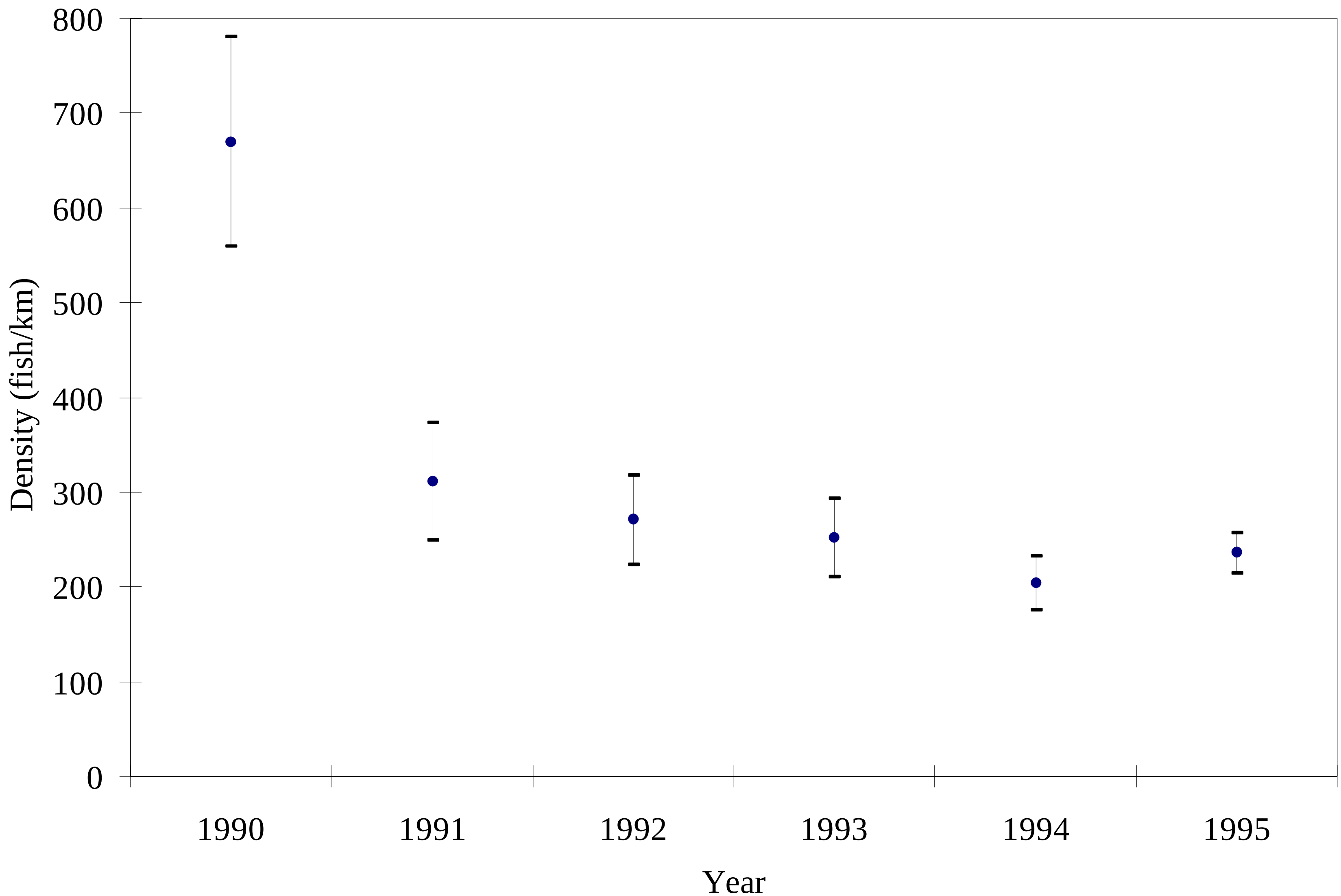

Figure 6.-Estimated density of Arctic grayling ≥ 150 mm FL in the Chatanika River study area from 1990 to 1995 (solid circles are point estimates and vertical bars are ± 1 SE).

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LITERATURE CITED

Baker, T. T. 1988. Creel censuses in interior Alaska in 1987. Alaska Department of Fish and Game, Fishery Data Series Number 64, Juneau.

Bailey, N. T. J. 1951. On estimating the size of mobile populations from capture-recapture data. Biometrika 38: 293-306.

Bailey, N. T. J. 1952. Improvements in the interpretation of recapture data. Journal of Animal Ecology 21: 120-127.

Brown, C. J. D. 1943. Age and growth of Montana grayling. The Journal of Wildlife Management 7:353-364.

Clark, R. A. 1988. Stock assessment of Arctic grayling in the Salcha and Chatanika rivers. Alaska Department of Fish and Game, Fishery Data Series Number 74, Juneau.

Clark, R. A. and W. P. Ridder. 1987. Abundance and length composition of selected grayling stocks in the Tanana drainage during 1986. Alaska Department of Fish and Game, Fishery Data Series Number 26, Juneau.

Clark, R. A. and W. P. Ridder. 1988. Stock assessment of Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game, Fishery Data Series Number 54, Juneau.

Clark, R. A. and W. P. Ridder. 1990. Stock assessment of Arctic grayling in the Salcha, Chatanika, and Goodpaster rivers. Alaska Department of Fish and Game, Fishery Data Series Number 90-7, Anchorage.

Clark, R. A., D. F. Fleming, and W. P. Ridder. 1991. Stock assessment of Arctic grayling in the Salcha, Chatanika, and Goodpaster rivers. Alaska Department of Fish and Game, Fishery Data Series Number 91-15, Anchorage.

Darroch, J. N. 1961. The two-sample capture-recapture census when tagging and sampling are stratified. Biometrika 48:241-260.

Evenson, M. J. 1988. Movement, abundance and length composition of Tanana River burbot stocks during 1987. Alaska Department of Fish and Game. Fishery Data Series Number 56, Juneau.

Fleming, D. F., R. A. Clark, and W. P. Ridder. 1992. Stock assessment of Arctic grayling in the Salcha, Chatanika, Goodpaster, and Delta Clearwater rivers. Alaska Department of Fish and Game, Fishery Data Series Number 92-17, Anchorage.

Gabelhouse, D. W. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management 4:273-285.

Hallberg, J. E. 1982. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1981-1982, Project F-9-14, 23(R-I). 35 pp.

Holmes, R. A. 1983. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1982-1983, Project F-9-15, 24(R-I). 35 pp.

Holmes, R. A. 1985. Population structure and dynamics of Arctic grayling, with emphasis on heavily fished stocks. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1984-1985, Project F-9-17, 26(R-I). 38 pp.

Holmes, R. A., W. P. Ridder, and R. A. Clark. 1986. Population structure and dynamics of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1985-1986, Project F-10-1, 27(G-8-1). 68 pp.

Holmes, R. A., D. N. McBride, T. Viavant, and J. B. Reynolds. 1990. Electrofishing induced mortality and injury to rainbow trout, Arctic grayling, humpback whitefish, least cisco, and northern pike. Alaska Department of Fish and Game, Fishery Manuscript Series Number 90-3, Anchorage.

Kramer, M. J. 1975. Inventory and cataloging of interior Alaska waters - Fairbanks district. Alaska Department of Fish and Game. Federal Aid in Sport Fish Restoration, Annual Report of Progress, 1974-1975, Project F-9-7, 16(G-I-G): 145-181.

Kruse, T. E. 1959. Grayling of Grebe Lake, Yellowstone National Park, Wyoming. U.S. Fish and Wildlife Service Fishery Bulletin 59:307-351.

Marquardt, D. W. 1963. An algorithm for least-squares estimation of nonlinear parameters. Journal for the Society of Industrial and Applied Mathematics 11: 431-441.

Mills, M. J. 1979. Alaska statewide sport fish harvest studies (1977). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1978-1979, Project F-9-11, 20(SW-I-A). 122 pp.

Mills, M. J. 1980. Alaska statewide sport fish harvest studies (1978). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1979-1980, Project F-9-12, 21(SW-I-A). 65 pp.

Mills, M. J. 1981a. Alaska statewide sport fish harvest studies (1979). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22(SW-I-A). 77 pp.

Mills, M. J. 1981b. Alaska statewide sport fish harvest studies (1980). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22(SW-I-A). 107 pp.

Mills, M. J. 1982. Alaska statewide sport fish harvest studies (1981). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1981-1982, Project F-9-14, 23(SW-I-A). 115 pp.

Mills, M. J. 1983. Alaska statewide sport fish harvest studies (1982). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1982-1983, Project F-9-15, 24(SW-I-A). 118 pp.

Mills, M. J. 1984. Alaska statewide sport fish harvest studies (1983). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1983-1984, Project F-9-16, 25(SW-I-A). 123 pp.

Mills, M. J. 1985. Alaska statewide sport fish harvest studies (1984). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1984-1985, Project F-9-17, 26(SW-I-A). 137 pp.

Mills, M. J. 1986. Alaska statewide sport fish harvest studies (1985). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1985-1986, Project F-10-1, 27(RT-2). 137 pp.

Mills, M. J. 1987. Alaska statewide sport fisheries harvest report (1986). Alaska Department of Fish and Game, Fishery Data Series Number 2, Juneau.

Mills, M. J. 1988. Alaska statewide sport fisheries harvest report (1987). Alaska Department of Fish and Game, Fishery Data Series Number 52, Juneau.

Mills, M. J. 1989. Alaska statewide sport fisheries harvest report (1988). Alaska Department of Fish and Game, Fishery Data Series Number 122, Juneau.

Mills, M. J. 1990. Harvest and participation in Alaska sport fisheries during 1989. Alaska Department of Fish and Game, Fishery Data Series Number 90-44, Anchorage.

LITERATURE CITED (Continued)

Mills, M. J. 1991. Harvest, catch, and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series Number 91-58, Anchorage.

Mills, M. J. 1992. Harvest, catch, and participation in Alaska sport fisheries during 1991. Alaska Department of Fish and Game, Fishery Data Series Number 92-40, Anchorage.

Mills, M. J. 1993. Harvest, catch, and participation in Alaska sport fisheries during 1992. Alaska Department of Fish and Game, Fishery Data Series Number 93-42, Anchorage.

Mills, M. J. 1994. Harvest, catch, and participation in Alaska sport fisheries during 1993. Alaska Department of Fish and Game, Fishery Data Series Number 94-28, Anchorage.

Reynolds, J. B. 1983. Electrofishing. Pages 147-163 *in* L. A. Nielsen and D. L. editors. Fisheries techniques. American Fisheries Society, Bethesda, Maryland.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada Number 191. 382 pp.

Ridder, W. P., T. R. McKinley, and R. A. Clark. 1993. Stock assessment of Arctic grayling in the Salcha, Chatanika, Goodpaster rivers during 1992. Alaska Department of Fish and Game, Fishery Data Series Number 93-11, Anchorage.

Roach, S. M. 1994. Stock assessment of Arctic grayling in the Salcha, Chatanika, and Goodpaster rivers during 1993. Alaska Department of Fish and Game, Fishery Data Series Number 94-13, Anchorage.

Roach, S. M. 1995. Stock assessment of Arctic grayling in the Salcha, Chatanika, and Goodpaster rivers during 1994. Alaska Department of Fish and Game, Fishery Data Series Number 95-9, Anchorage.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters. Charles Griffin and Co., Ltd. London, U.K.

Tack, S. L. 1973. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1972-1973, Project F-9-5, 14(R-1). 34 pp.

Tack, S. L. 1980. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1971-1980. Project F-9-12, 21(R-I). 32 pp.

Van Hulle, F. D. 1968. Investigations of fish populations in the Chena River. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1967-1968, Project F-5-R-9, 9:287-304.

Warner, G. 1959. Catch distribution, age and size composition sport fish in Fairbanks area. U.S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report. Project F-1-R-8, Work Plan A, Job 3c, 8(3). 7 pp.

Wojcik, F. J. 1954. Game fish investigations of Alaska. U.S. Fish and Wildlife Service and Alaska Game Commission. Federal Aid in Fish Restoration, Work Plan Number 5, Job Number 1.

Wojcik, F. J. 1955. Life history and management of the grayling in interior Alaska. M.S. Thesis, University of Alaska - Fairbanks.

APPENDIX A

Historic Data Summary

Appendix A1.-Number of interviews, angler-hours, and harvest rates (fish/hr) for Arctic grayling harvested from the Chatanika River summarized by year[a].

Year	Interviews	Angler-hours	Fish/Hr[b]
1953	460	955	0.49
1954	243	529	0.78
1955[c]	69	294	0.13
1956[c]	66	223	0.27
1957[c]	62	177	0.18
1958[c]	68	151	0.76
1974	408	27,250[d]	1.02
1987	30	---	0.02

[a] Data taken from Warner (1959) for 1953-1958, Kramer (1975) for 1974, and Baker (1988) for 1987.

[b] AG/hr is the number of Arctic grayling harvested per angler-hour.

[c] From 1955 through 1958 there was a 305 mm (12 inch) minimum length limit for Arctic grayling on the Chatanika River (Warner 1959).

[d] Data from sample time per area expanded to the entire fishery.

Appendix A2.-Study area, number of marks, number of recaptures, and estimated densities (fish/km) of Arctic grayling studies the Chatanika River by dates for 1972, 1981, 1984-1985, 1990-1995[a].

Dates	Area	Marks	Recaps	Density[b]	Confidence[c]
8/10/72 - 8/17/72	Elliott Highway bridge	103	4	305/km	Low
8/24/81 - 8/26/81	Elliott Highway bridge	ND[d]	64	169/km	132-197/km
8/15/84 - 8/18/84	Elliott Highway bridge	ND	32	242/km	172-352/km
8/20/85 - 8/23/85	Elliott Highway bridge	132	20	117/km	82-176/km
8/27/90 - 9/7/90	28.8 km section from 7.5 km above the Elliott Highway bridge downstream to Any Creek	857	36	670/km	SE = 111/km
8/12/91-8/15/91	35.2 km section from 9.6 km above the Elliott Highway bridge downstream to Any Creek	608	58	312/km	SE = 62/km
7/11/91 - 7/16/91; 8/23/91 - 8/26; 9/9/91 - 9/14/91	73.8 km section from Any Creek to Murphy Dome Road extension	667	25	271/km	SE = 52/km
8/17/92 - 8/28/92	29.6 km section from 3.2 km above the Elliott Highway bridge downstream to Any Creek	679	41	271/km	SE = 47/km
	73.8 km section from Any Creek to Murphy Dome Road extension	1,767	224	158/km	SE = 17/km
8/16/93 - 8/26/93	29.6 km section from 3.2 km above the Elliott Highway bridge downstream to Any Creek	617	32	252/km	SE = 41/km
	50 km section from Any Creek to 16 km above Murphy Dome Road extension	758	89	89/km	SE = 9/km
8/15/94 - 8/24/94	29.6 km section from 3.2 km above the Elliott Highway bridge downstream to Any Creek	648	55	201/km	SE = 28/km
6/19/95 - 6/30/95	37.8 km section from 3.2 km above the Elliott Highway bridge to 8.2 km downstream of Any Creek	862	51	236/km	SE = 21/km

[a] Data sources: 1972 (Tack 1973); 1982 (Holmes 1983); 1984 (Holmes 1985); 1985 (Holmes et al. 1986); 1990 (Clark et al. 1991); 1991 (Fleming et al. 1992); 1992 (Ridder et al. 1993); 1993 (Roach 1994); 1994 (Roach 1995) and, 1995 (present report).

[b] All estimates except 1990 through 1995 were calculated with the modified Schnabel formula (Ricker 1975). The 1990 and 1995 estimates were calculated with the modified Petersen estimator of Evenson (1988) and the modified Petersen estimate of Bailey (1951, 1952). The 1991 through 1994 estimates used the modified Petersen estimate of Bailey (1951, 1952).

[c] Confidence is a crude measure of precision (e.g. Low), the 95% confidence interval based on a Poisson distribution of recaptures (Ricker 1975), or the standard error.

[d] ND = data not furnished in original citation.

Appendix A3.-Summary of age composition estimates and standard error of Arctic grayling (≥ 150 mm FL) collected from the Chatanika River, 1984-1995[a].

	1984[b]			1985[c]			1986[d]			1987[e]			1988[f]			1989[g]		
Age	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE
2	2	0.04	0.03	131	0.55	0.03	0	0.00	---	11	0.02	0.01	22	0.04	0.01	24	0.09	0.03
3	8	0.14	0.05	5	0.02	0.01	119	0.31	0.02	50	0.09	0.01	44	0.09	0.01	47	0.18	0.04
4	22	0.39	0.07	31	0.13	0.02	16	0.04	0.01	295	0.55	0.02	63	0.12	0.01	31	0.12	0.03
5	17	0.30	0.06	59	0.25	0.03	71	0.18	0.02	32	0.06	0.01	216	0.42	0.02	30	0.08	0.02
6	5	0.09	0.04	12	0.05	0.01	119	0.31	0.02	47	0.09	0.01	48	0.09	0.01	88	0.23	0.04
7	1	0.02	0.02	0	0.00	---	47	0.12	0.02	106	0.19	0.02	55	0.11	0.01	54	0.14	0.03
8	1	0.02	0.02	0	0.00	---	12	0.03	0.01	8	0.01	0.01	61	0.12	0.01	47	0.12	0.03
9	0	0.00	---	0	0.00	---	2	0.01	0.00	3	0.01	<0.01	5	0.01	<0.01	15	0.04	0.01
10	0	0.00	---	0	0.00	---	0	0.00	---	1	<0.01	<0.01	1	<0.01	<0.01	2	0.01	<0.01
Totals	56	1.00		238	1.00		386	1.00		553	1.00		515	1.00		338	1.00	

-continued-

Appendix A3.-Page 2 of 3.

	1990[h]			1991[i]			1992[j]			1993[k]			1994[l]			1995[m]		
Age	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE
2	126	0.02	0.02	26	0.05	0.01	56	0.14	0.03	88	0.15	0.02	6	0.02	0.01	56	0.11	0.01
3	347	0.55	0.02	88	0.17	0.02	32	0.08	0.01	123	0.21	0.02	64	0.19	0.02	40	0.08	0.01
4	80	0.11	0.01	226	0.44	0.02	83	0.22	0.03	26	0.04	0.01	100	0.29	0.02	119	0.24	0.02
5	45	0.04	0.01	46	0.09	0.01	198	0.36	0.03	100	0.16	0.02	32	0.09	0.02	153	0.31	0.02
6	51	0.04	0.01	36	0.07	0.01	81	0.11	0.01	162	0.25	0.02	45	0.13	0.02	40	0.08	0.01
7	57	0.04	0.01	47	0.09	0.01	30	0.03	0.01	57	0.08	0.02	52	0.14	0.02	50	0.10	0.01
8	17	0.01	<0.01	29	0.06	0.01	39	0.04	0.01	27	0.04	0.01	25	0.07	0.01	25	0.05	<0.01
9	11	0.01	<0.01	12	0.02	0.01	28	0.03	0.01	20	0.03	0.01	10	0.03	0.01	6	0.01	<0.01
10	2	<0.01	<0.01	4	0.01	<0.01	10	0.01	<0.01	17	0.02	0.01	8	0.02	0.01	1	<0.01	<0.01
11	0	---	---	1	<0.01	<0.01	1	<0.01	<0.01	10	0.01	0.01	3	0.01	0.01	0	---	---
12	---	---	---	---	---	---	---	---	---	7	0.01	0.01	5	0.01	0.01	1	<0.01	<0.01
13	---	---	---	---	---	---	---	---	---	1	<0.01	<0.01	1	<0.01	<0.01	---	---	---
Totals	736	1.00		515	1.00		558	1.00		668	1.00		351	1.00		491	1.00	

-continued-

[a] Source documents are: 1984 (Holmes 1985); 1985 (Holmes et al. 1986); 1986 (Clark and Ridder 1987); 1987 (Clark and Ridder 1988); 1988 (Clark 1988); 1989 (Clark and Ridder 1990); 1990 (Clark et al. 1991); 1991 (Fleming et al. 1992); 1992 (Ridder et al. 1993); 1993 (Roach 1994); 1994 (Roach 1995); and, 1995 (present report).

[b] Sampling was conducted with an AC electrofishing boat near the Elliott Highway bridge (15-18 August 1984).

[c] Sampling was conducted with an AC electrofishing boat near the Elliott Highway bridge (20-23 August 1985).

[d] Sampling was conducted with a DC electrofishing boat near the Elliott Highway bridge (4-28 August 1986).

[e] Sampling was conducted with a DC electrofishing boat near the Elliott Highway bridge (10-13 August 1987).

[f] Sampling was conducted with a DC electrofishing boat near the Elliott Highway bridge (15-26 August and 7-20 September 1988).

[g] Sampling was conducted with a DC electrofishing boat downstream of the Elliott Highway bridge (12 through 28 September 1989). Age composition and standard error are adjusted for differential probability of capture by size of fish.

[h] Sampling was conducted with a DC electrofishing boat in a 28.8 km section, beginning 7.5 km upstream of the Elliott Highway bridge and ending 21.3 km downstream of the bridge (27 August through 7 September 1990). Age composition and standard error are adjusted for differential probability of capture by size of fish.

[i] Sampling was conducted with a DC electrofishing boat in a 35.2 km section, beginning 9.6 km upstream of the Elliott Highway bridge and ending 25.6 km downstream of the bridge (5 through 7 August 1991).

[j] Sampling was conducted with a DC electrofishing boat in a 101 km section, beginning 3.2 km upstream of the Elliott Highway bridge and ending downstream at the Murphy Dome Road terminus (24 through 28 August 1992). Age composition and standard error are adjusted for differential probability of capture by size of fish.

[k] Sampling was conducted with a DC electrofishing boat in a 78.2 km section, beginning 3.2 km above the Elliott Highway bridge and ending downstream 24 km above Murphy Dome Road extension (23 through 26 August 1993).

[l] Sampling was conducted with a DC electrofishing boat in a 29.6 km section, beginning 3.2 km above the Elliott Highway bridge and ending downstream to Any Creek (22 through 24 August 1994).

[m] Sampling was conducted with a DC electrofishing boat in a 37.8 km section, beginning 3.2 km above the Elliott Highway bridge and ending 8.2 km downstream of Any Creek (28 through 30 June 1995).

Appendix A4.-Summary of mean length at age data collected from Arctic grayling in the Chatanika River, 1952-1953, 1981-1982, 1984-1995.

	1952			1953			1981			1982			1984			1985		
Age	n[b]	FL[c]	SD[d]	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	ND	94	---	19	96	---	0	---	---	5	95	---	16	101	---	0	---	---
2	ND	133	---	77	144	---	4	169	---	29	135	---	3	149	---	131	147	15
3	ND	176	---	129	190	---	7	204	---	22	187	---	8	172	---	5	181	25
4	ND	212	---	28	207	---	10	233	---	23	216	---	22	196	---	31	212	22
5	ND	243	---	4	226	---	7	264	---	5	236	---	17	225	---	59	233	24
6	---	---	---	9	254	---	3	286	---	2	280	---	5	251	---	12	268	18
7	---	---	---	---	---	---	1	290	---	1	252	---	1	258	---	---	---	---
8	---	---	---	---	---	---	---	---	---	1	334	---	1	301	---	---	---	---
9	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
10	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Totals	149			266			32			87			73			238		

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	1986			1987			1988			1989			1990			1991		
Age	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	---	---	---	---	---	---	---	---	---	4	125	16	19	125	10	---	---	---
2	---	---	---	11	157	15	22	170	13	30	159	27	143	167	14	26	165	9
3	119	195	21	50	200	24	44	205	16	47	203	38	351	195	17	87	204	22
4	16	231	36	295	228	18	63	238	21	31	234	42	80	242	18	227	227	21
5	71	248	16	32	265	22	216	259	22	30	267	56	45	269	15	46	264	27
6	119	267	20	47	273	21	48	278	24	88	286	36	52	282	19	36	285	17
7	47	292	28	106	288	30	55	298	22	54	305	46	61	297	22	48	300	29
8	12	304	21	8	319	18	61	312	25	47	313	49	17	324	23	29	314	29
9	2	283	35	3	296	55	5	328	8	15	334	86	11	329	12	12	317	40
10	---	---	---	1	325	---	1	352	---	2	337	147	2	337	34	3	334	6
Totals	386			553			515			349			781			514		

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	1992			1993			1994			1995		
Age	n	FL	SD	n	FL	SD	n	FL	SD	n	FL	SD
1	---	---	---	1	195	---	---	---	---	---	---	---
2	56	175	22	88	172	17	6	182	7	67	164	23
3	32	213	24	123	204	22	64	212	27	46	216	19
4	83	248	26	26	243	23	100	243	25	140	241	26
5	198	262	24	100	270	23	32	267	22	176	264	21
6	81	289	21	162	284	21	45	288	27	43	291	30
7	30	310	22	57	300	19	52	301	29	54	312	30
8	39	320	16	27	317	17	25	312	40	29	315	26
9	28	337	24	20	322	23	10	331	18	6	307	61
10	10	329	21	17	334	12	8	341	15	1	379	---
11	1	350	---	10	345	20	3	369	15	---	---	---
12	---	---	---	7	344	10	5	344	13	1	352	---
13	---	---	---	1	362	---	1	376	---	---	---	---

[a] Data sources: 1952-1953 (Warner 1959); 1981 (Hallberg 1982); 1982 (Holmes 1983); 1984 (Holmes 1985); 1985 (Holmes et al. 1986); 1986 (Clark and Ridder 1987); 1987 (Clark and Ridder 1988); 1988 (Clark 1988); 1989 (Clark and Ridder 1990); 1990 (Clark et al. 1991); 1991 (Fleming et al. 1992); 1992 (Ridder et al. 1993); 1993 (Roach 1994); 1994 (Roach 1995); and, 1995 (present report).

[b] n is the total number of fish aged.

[c] FL is the mean fork length (mm) at age.

[d] SD is the standard deviation of FL.

Appendix A5.-Summary of estimated RSD categories for Arctic grayling within the Chatanika River by year[a].

Year		RSD Category[b]				
		Stock	Quality	Preferred	Memorable	Trophy
1952	Number	95	1	0	0	0
	RSD	0.99	0.01	---	---	---
	SE	0.01	0.01	---	---	---
1953	Number	98	8	0	0	0
	RSD	0.92	0.08	---	---	---
	SE	0.03	0.03	---	---	---
1954	Number	42	1	0	0	0
	RSD	0.98	0.02	---	---	---
	SE	0.02	0.02	---	---	---
1972	Number	121	0	0	0	0
	RSD	1	---	---	---	---
	SE	---	---	---	---	---
1982	Number	53	3	0	0	0
	RSD	0.95	0.05	---	---	---
	SE	0.03	0.03	---	---	---
1984	Number	206	9	1	0	0
	RSD	0.95	0.04	0.01	---	---
	SE	0.01	0.01	0.01	---	---
1985	Number	146	11	0	0	0
	RSD	0.93	0.07	---	---	---
	SE	0.02	0.02	---	---	---
1986	Number	279	121	4	0	0
	RSD	0.69	0.3	0.01	---	---
	SE	0.02	0.02	0.01	---	---
1987	Number	420	126	7	0	0
	RSD	0.76	0.23	0.01	---	---
	SE	0.02	0.02	0.01	---	---
1988	Number	361	221	13	0	0
	RSD	0.61	0.37	0.02	---	---
	SE	0.02	0.02	0.01	---	---
1989	Number	150	221	4	0	0
	RSD[c]	0.49	0.49	0.02	---	---
	SE	0.06	0.06	0.01	---	---
1990	Number	1,201	309	19	0	0
	RSD[c]	0.9	0.09	0.01	---	---
	SE	0	0.02	<0.01	---	---
1991[d]	Number	516	222	25	0	0
	RSD[c]	0.84	0.14	0.02	---	---
	SE	0.03	0.03	<0.01	---	---

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Year		RSD Category				
		Stock	Quality	Preferred	Memorable	Trophy
1991[e]	Number	381	312	56	0	0
	RSD	0.51	0.42	0.07	---	---
	SE	0.02	0.02	0.01	---	---
1992[i]	Number	294	134	9	0	0
	RSD[c]	0.84	0.15	0.01	---	---
	SE	0.03	0.03	<0.01	---	---
1992[g]	Number	1,250	1,507	175	0	0
	RSD[c]	0.44	0.5	0.06	---	---
	SE	0	0	<0.01	---	---
1993[d]	Number	226	155	9	0	0
	RSD[c]	0.58	0.4	0.02	---	---
	SE	0.03	0.03	<0.01	---	---
1993[h]	Number	215	279	34	0	0
	RSD[c]	0.41	0.53	0.06	---	---
	SE	0.02	0.02	0.01	---	---
1994[d]	Number	639	410	74	0	0
	RSD[c]	0.57	0.36	0.07	---	---
	SE	0.02	0.02	0.01	---	---
1995[i]	Number	374	199	20	0	0
	RSD	0.63	0.34	0.03	---	---
	SE	0.02	0.02	0.01	---	---

[a] Data sources: 1952-1958 (Warner 1959); 1972 (Tack 1973); 1982 (Holmes 1983); 1984 (Holmes 1985); 1985 (Holmes et al. 1986); 1986 (Clark and Ridder 1987); 1987 (Clark and Ridder 1988); 1988 (Clark 1988); 1989 (Clark and Ridder 1990); 1990 (Clark et al. 1991); 1991 (Fleming et al. 1992); 1992 (Ridder et al. 1993); 1993 (Roach 1994); 1994 (Roach 1995); and, 1995 (present report).

[b] Minimum lengths for RSD categories are (adapted from Gabelhouse 1984): stock (150 - 169 mm FL); quality (270 - 339 mm FL); preferred (340 - 449 mm FL); memorable (450 - 559 mm FL); and, trophy (560 mm FL and greater).

[c] RSD does not correspond to sample size because of adjustments made for differential capture probability by size of fish or area.

[d] 29.6 km section from 3.2 km above the Elliott Highway bridge downstream to Any Creek.

[e] 83.2 km section from 25.6 km below the Elliott Highway bridge to Murphy Dome Extension Rd.

[f] 35.2 km section from 9.6 km above the Elliott Highway bridge downstream to below Any Creek.

[g] 73.8 km section from 25.6 km below the Elliott Highway bridge to Murphy Dome Extension Rd.

[h] 50 km section from 25.6 km below the Elliott Highway bridge to 24 km above Murphy Dome Extension Rd.

[i] 37.8 km section from 3.2 km above Elliott Highway bridge downstream to 8.2 km below Any Creek.

Appendix A6.-Parameter estimates and standard errors of the von Bertalanffy growth model[a] for Arctic grayling from the Chatanika River, 1986-1988[b].

	Chatanika River	
Parameter	Estimate	Standard Error
$L\infty$[c]	375	11
K[d]	0.19	0.02
t_o[e]	-1.01	0.2
Corr($L\infty$,K)[f]	-0.98	---
Corr($L\infty$,t_o)	-0.89	---
Corr(K,t_o)	0.96	---
Sample size	1,469	

[a] The von Bertalanffy growth model (Ricker 1975) used was **Error! Objects cannot be created from editing field codes.**. The parameters of this model were estimated with data collected during 1986 through 1988. This model was fitted to the data by nonlinear regression utilizing the Marquardt compromise (Marquardt 1963). The range of ages used to model growth were age 1 through age 10.

[b] Source citation is Clark (1988).

[c] $L\infty$ is the length a fish would achieve if it continued to live and grow indefinitely (Ricker 1975).

[d] K is a constant that determines the rate of increase of growth increments (Ricker 1975).

[e] t_0 represents the hypothetical age at which a fish would have zero length (Ricker 1975).

[f] Corr(x,y) is the correlation of parameter estimates x and y.

APPENDIX B

Equations and Statistical Methodology

Appendix B1.-Methodology to compensate for bias due to unequal catchability by river section.

Case	Result of χ^2 Test[a]	Inspection of Fish Movement[b]	Inferred Cause
I[c]	Fail to reject H_o	No movement between sections	There is no differential capture probability by river section or marked fish completely mixed with unmarked fish within each river section.
II[d]	Fail to reject H_o	Movement between sections	There is no differential capture probability by river section or marked fish completely mixed with unmarked fish across river sections.
III[e]	Reject H_o	No movement between sections	There is differential capture probability by river section or marked fish did not mix completely with unmarked fish within at least one river section.
IV[f]	Reject H_o	Movement between sections	Inferred cause: There is differential capture probability by river section or marked fish did not mix completely with unmarked fish across river sections.

[a] The chi-squared test compares the frequency of marked fish recaptured during the second event in each river section with the frequency of unmarked fish examined in the second event in each river section. H_o for this test is: capture probability of marked fish in the second event is the same in all river sections.

[b] Inspection of fish movement is a visual comparison of the frequency of marked fish recaptured in the second event that moved from one river section to another with the frequency of unmarked fish examined in the second event in each river section.

[c] Case I: Calculate one unstratified abundance estimate using the Bailey (1951, 1952) estimator.

[d] Case II: Calculate one unstratified abundance estimate using the Bailey (1951, 1952) estimator and calculate one unstratified abundance estimate using the "movement" (Evenson 1988) estimator. If estimates are dissimilar, discard the Bailey estimate and use the movement estimate as the estimate of abundance. If estimates are similar, discard the movement estimate and use the Bailey estimate as the estimate of abundance.

[e] Case III: Completely stratify the experiment by river section, calculate abundance estimates for each using the Bailey (1951, 1952) estimator, and sum abundance estimates.

[f] Case IV: Completely stratify the experiment by river section. Calculate abundance estimates for each using the Bailey (1951, 1952) estimator and sum estimates. If movement out of the sample area is neither probable nor possible, calculate abundance with the partially stratified model of Darroch (1961) and compare with the sum of Bailey estimates. If estimates are dissimilar, discard the sum of Bailey estimates and use the Darroch estimate as the estimate of abundance. If estimates are similar, discard the estimate with the largest variance. If movement out of the sample area is probable, calculate abundance with the movement (Evenson 1988) estimator and compare with the sum of Bailey estimates. If estimates are dissimilar, discard the sum of Bailey estimates and use the movement estimate as the estimate of abundance (note: this estimate will be biased). If estimates are similar, discard the movement estimate and proceed as if movement were neither probable nor possible.

Appendix B2.-Methodology to compensate for bias due to gear selectivity by means of statistical inference.

Case	Result of First K-S Test	Result of second K-S test[b]	Inferred Cause
I[c]	Fail to reject H_o	Fail to reject H_o	There is no size-selectivity during either sampling event.
II[d]	Fail to reject H_o	Reject H_o	There is no size-selectivity during the second sampling event, but there is during the first sampling event.
III[e]	Reject H_o	Fail to reject H_o	There is size-selectivity during both sampling events.
IV[f]	Reject H_o	Reject H_o	There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.

[a] The first K-S (Kolmogorov-Smirnov) test is on the lengths of fish marked during the first event versus the lengths of fish recaptured during the second event. H_o for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish recaptured during the second event.

[b] The second K-S test is on the lengths of fish marked during the first event versus the lengths of fish captured during the second event. H_o for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish sampled during the second event.

[c] Case I: Calculate one unstratified abundance estimate, and pool lengths and ages from both sampling events for size and age composition estimates.

[d] Case II: Calculate one unstratified abundance estimate, and only use lengths and ages from the second sampling event to estimate size and age composition.

[e] Case III: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Pool lengths and ages from both sampling events and adjust composition estimates for differential capture probabilities.

[f] Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Also calculate a single abundance estimate without stratification.

Case IVa: If stratified and unstratified estimates are dissimilar, discard unstratified estimate and use lengths and ages from second event and adjust these estimates for differential capture probabilities.

Case IVb: If stratified and unstratified estimates are similar, discard estimate with largest variance. Use lengths and ages from first sampling event to directly estimate size and age compositions.

Appendix B3.-Equations used to estimate abundance and variance.

Abundance ($\hat{N}$)and Variance of Abundance($\hat{V}\left[\hat{N}\right]$)

Bailey (1951,1952) estimate of abundance as modified by Seber (1982):

$$\hat{N} = \frac{M(C+1)}{R+1} \tag{B3.1}$$

where: M = the number of Arctic grayling marked and released alive during the first sample;

C = the number of Arctic grayling examined for marks during the second sample;

R = the number of Arctic grayling recaptured during the second sample,

$\hat{N}$ = estimated abundance of Arctic grayling during the first sample.

Variance estimated by (Seber 1982):

$$\hat{V}\left[\hat{N}\right] = \frac{M^2(C+1)(C-R)}{(R+1)^2(R+2)}. \tag{B3.2}$$

Bailey (1951, 1952) estimate of abundance as modified by Evenson (1988)for movement out of the study area:

$$\hat{N} = \frac{\left[M_1\left(1-\hat{\theta}_d\right) + M_2 + M_3\left(1-\hat{\theta}_u\right)\right]\left[C+1\right]}{R_{..}+1} \tag{B3.3}$$

where: M_x = the number of Arctic grayling marked and released alive during the first sample in section x; downstream section (x = 1), midstream section (x = 2), or upstream section (x =3);

$\hat{\theta}_z$ = the probability that a fish will move out of an area in the *z* direction (upstream or downstream);

C = the number of Arctic grayling examined for marks during the second sample;

$R_{..}$ = the number of fish recaptured during the second event; and,

$\hat{N}$ = the abundance of fish in all sections at the start of the second event.

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Abundance ($\hat{N}$)and Variance of Abundance($\hat{V}\left[\hat{N}\right]$)

The probabilities of movements were estimated as:

$$\hat{\theta}_d = \frac{M_2\left(R_{32} + R_{21}\right)}{R_{2\cdot}\left(M_3 + M_2\right)}, \text{ and} \tag{B3.4}$$

$$\hat{\theta}_u = \frac{M_2\left(R_{12} + R_{23}\right)}{R_{2\cdot}\left(M_1 + M_2\right)} \tag{B3.5}$$

where: R_{xy} = the number of fish that were marked in section *x* during the first event and were recaptured in section *y* during the second event; and,

$R_{2\cdot}$ = the number of fish that were marked in the midstream section during the first event and were recaptured during the second event.

Appendix B4.-Equations used to estimate age and length compositions when no adjustments were needed and when adjustments were needed to compensate for bias due to differential capture probability by size of fish or river section.

Proportions by Length or Age ($\hat{p}_k$) and Variance of Proportions ($\hat{V}[\hat{p}_k]$)

Proportion and variance estimator used when no adjustments were needed:

$$\hat{p}_k = \frac{x_k}{n}, \text{ and} \tag{B4.1}$$

$$\hat{V}[\hat{p}_k] = \frac{p_k(1-p_k)}{n-1} \tag{B4.2}$$

where: $\hat{p}_k$ = the proportion of fish that are age or size *k*;

x_k = the number of fish sampled that are age or size *k*; and,

n = the number of fish sampled that were aged or measured.

Proportion and variance estimator used when adjustments were needed:

$$\hat{p}_k = \sum_{i=1}^{j} \frac{\hat{N}_i}{\hat{N}} \hat{p}_{ik}, \text{ and} \tag{B4.3}$$

$$\hat{V}[\hat{p}_k] \approx \sum_{i=1}^{j} (\hat{p}_{ik} - \hat{p}_k)^2 \frac{\hat{V}[\hat{N}_i]}{\hat{N}^2} + \sum_{i=1}^{j} \left(\frac{\hat{N}_i}{\hat{N}}\right)^2 \hat{V}[\hat{p}_{ik}] \tag{B4.4}$$

where: $\hat{N}_i$ = the abundance of Arctic grayling in stratum *i*;

$\hat{N}$ = total abundance; and,

$\hat{p}_{ik}$ = the proportion of fish in stratum *i* that were age or size *k*.

APPENDIX C

Data File Listing

Appendix C1.-Data files used to estimate parameters of the Arctic grayling population in the Chatanika River, 1995.

Data file[a]	Description
U004ALA5.DTA	Population and marking data for Arctic grayling captured during the marking event at the Chatanika River, 19 through 21 June 1995.
U004BLA5.DTA	Population and marking data for Arctic grayling captured during the recapture event at the Chatanika River, 28 through 30 June 1995.

[a] Data files were archived at and are available from the Alaska Department of Fish and Game, Sport Fish Division, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska 99518-1599.